

The Degradation of Particleboard Strength

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ABSTRACT A number of references about the degradation of particleboard strength were reviewed. Evidences indicate that PF adhesives are hydrolytically stable and yet particleboards bonded with these resins still degrade. The main causes of degradation of PF bonded particleboard are the reversal of densification and the development of glue line stresses.

Keywords: Particleboard, Strength degradation, PF and UF adhesives

Although PF resins are generally recognized to be much durable than UF resins, there is not a clear difference between particleboards bonded with these two adhesives. In fact, a number of researchers have found UF resin bonded particleboards and PF resin bonded particleboards to display the similar short term physical properties at low humidity and temperature (Lee and Biblis 1976, Dexin and Ostman 1983, Sekino and Suzuki 1984). A series of experiments designed to assess the durability of commercial particleboards has been carried out over a number of years and a large data-base of physical properties, has been collected by Dinwoodie and his colleagues (1978, 1981, 1984, 1985) and Pierce et al (1986) of the Building Research Establishment. From their results, there seems little difference in short term properties such as modulus of rupture, modulus of elasticity, internal bond strength and thickness swelling, between particleboards made with different adhesives, particularly between urea and phenol formaldehyde bonded boards.

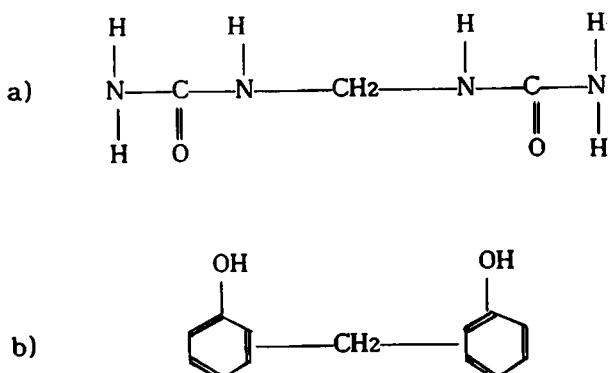


Fig. 1. The methylene linkage in PF and UF resins

a) methylene diurea b) Diphenyl methane

This is thought to be due to the fact that UF and PF resins form similar types of bonds within their matrices and with wood. When these adhesives are cured at high temperature, the methylene bridge is the predominant linkage (Fig. 1)(Pizzi 1983). As polar polymers, both of

them owe much of their dry strength and stiffness to hydrogen bonding. Evidence provided by Troughton (1969), Ramiah and Troughton (1970) have shown that formaldehyde based resins and wood cell wall cellulose are able to form covalent bonds through resin curing reactions. The most likely difference between the resin is the frequency of bonds formed, however, the fundamental similarity of bonding in the wood-glue system should result in the similar physical properties.

But the differences of physical properties between urea and phenol particleboards become significant as relative humidity and the temperature rise. Dexin and Ostman (1983) measured the effect of temperature and humidity on particleboard physical properties and concluded that a combination of high temperature and humidity caused the largest reduction in board strength. Dinwoodie (1978) exposed particleboards made with different resins to a environment of 87% relative humidity at 27 °C temperature for 25 weeks and found that the redried urea formaldehyde bonded boards retained only 66% of their original internal bond strength compared to 96% for PF resin bonded particleboards. The evidence given by Hann et al (1963) indicates that the long term exposure to 90% relative humidity at 27 °C causes a significant loss in strength and the strength loss is accompanied by an increase in thickness for all board types including those bonded with PF resin. They also found that a low relative humidity (20%) but high temperature of 70 °C only UF bonded boards showed significant strength loss. When cycled between these two environments, all boards including PF bonded particleboards showed rapid reductions in strength. Other researchers have also found that cycling between high and low humidity causes bond degradation more rapidly than a continuous high humidity. Lee and Biblis (1976) reported that after only one cycle of 65%, 30%, 65%, 90%, and 65% relative humidity at 25 °C a

PF bonded board lost 7.1% of its original internal bond strength. When subjected to natural weathering and accelerated aging, Barnes and Lyon (1978) found both UF and PF bonded boards degraded.

In 1968, Freeman and Kreibich concluded that hydrolysis was the main factor behind formaldehyde based resin degradation. They studied the durability of formaldehyde adhesives in alkaline (NH_4OH), neutral (water) and acidic (H_2SO_4) conditions and found that the quantity and the rate of formaldehyde evolved in the above hydrolytic solutions decreased in the order: urea formaldehyde resin, melamine urea formaldehyde resin, melamine formaldehyde resin, phenol formaldehyde resin and phenol resorcinol formaldehyde resin (Freeman and Kreibich 1968). This is in agreement with the findings of Troughton (1969) who examined the rate of formaldehyde emission on both pure resin and resin/wood mixtures, see Table 1. Phenol based adhesives were found to be non-hydrolysable by both researchers.

It has been found that acid catalysed PF adhesives do not form highly durable boards (Houwink and Salomon 1965, Raknes 1983). The likely cause of this poor performance is the hydrolysis of the wood surface.

Table 1 The hydrolysis rates of various formaldehyde based resins and wood flour mixtures from Troughton (1969)

Rank	Adhesive system	Acid-hydrolysis half-life at 80 °C	Activation energy (kJ/mole)
1	PF glue-wood	128 min.	~ 6.4
2	MF glue-wood	128 min.	5.0
3	MUF glue-wood	28 min.	4.5
4	UF glue-wood	5 min.	4.1

Three major factors and their interaction are the likely cause of the degradation of formaldehyde based resin bonded particleboards, i. e. the hydrolysis of the adhesives, the reversal of densification and the development of swelling stresses in wood glue lines.

In 1983, Beele published some results on the distribution of UF adhesives in particleboards. He found that the adhesives were able to penetrate the cell wall structure. Irle and Bolton (1988) used this evidence in their discussion on the possible cause of wood glue bond degradation in densified wood composites: they stated that "...cured resin inside the wall must form a polymerized continuum with the pure resin polymers of the adhesive phase. The resultant interphase must be a completely inseparable mix of adhesive and wood cell wall polymers. This makes it exceedingly unlikely that

bond failure will involve separation of the two polymer types; so the nature of the bonds between them and the hydrolysis resistance of these bonds, becomes much less important."

The above statement implies that the chemical stability of the adhesives may not be the main factor which causes the differences between UF and PF bonded particleboards. Evidence has been presented which indicates that PF adhesives are hydrolytically stable and yet particleboards bonded with these resins still degrade. From this, it must be concluded that the two physical factors i. e. The reversal of densification and the development of glue line stresses, are the main causes of degradation of PF bonded particleboards.

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